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THE EFFECT OF WINTER DEFOLIATION ON THE GROWTH OF PINE TREES AND THEIR SUSCEPTIBILITY TO INSECT ATTACK

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Forest Insect Laboratory
Coeur d'Alene, Idaho
Feb. 11, 1938

Refer to file
Studies C-8

Dr. F. C. Craighead
Washington
D. C.

Dear Dr. Craighead:

I am enclosing two copies of an office report concerning the effect of winter defoliation on the growth of pine trees and their susceptibility to insect attack, which has been prepared by Mr. Bedard. You will recall that the plots from which these data were taken were established in the spring of 1936, following the severe foliage injury of the previous winter. Your comments on this report will be appreciated.

Copy has been sent to the Experiment Station at Missoula, because of their interest in the problem and the fact that we have been working together in connection with these studies. Copies have also been sent to Miller, Keen, and Beal.

Respectfully yours,

James C. Evenden
Entomologist

Enclosures

THE EFFECT OF WINTER DEFOLIATION
ON THE GROWTH OF PINE TREES AND THEIR SUSCEPTIBILITY TO INSECT ATTACK

Time of Injury

During October and November 1935 a period of low temperatures occurred throughout most of the Northern Rocky Mountain region, and although the temperatures were not extreme for this region, they were preceded by abnormally warm weather well above freezing. In the vicinity of Coeur d'Alene, Idaho the cold weather occurred following a maximum of 48 and a minimum of 41 on October 28. During the next six days the maximum remained below freezing and the minimum went as low as 0°F. on November 1, resulting in the death of a considerable amount of pine foliage.

During the spring and summer of 1936, while the severity of the defoliation was yet apparent, a number of trees were marked to determine the effect of the defoliation on the trees and their susceptibility to subsequent insect attack. All trees were examined in the fall of 1936 and a report[1/] written concerning their condition at that time.

This report deals with the reexamination of the trees during the fall of 1937 and their condition two years after the defoliation. For convenience the report has been divided into three sections to include (1) western white pine reproduction, (2) mature western white pine, and (3) mature ponderosa pine.

1/ W. D. Bedard -- Memorandum for the files Re: Winter-killing of Pine Foliage. Report from the Coeur d'Alene Forest Insect Laboratory April 23, 1937.

Western White Pine Reproduction

Data for western white pine reproduction were secured from two sample plots,[1] one near Mullan, Idaho and the other in the pass at Lookout Summit. These plots include a total of 78 trees, which ranged in defoliation from zero to 100 percent. At the time the plots were established the following data were recorded: Height of tree, dominance, percent defoliated, and percent bud mortality. During the two subsequent examinations the length of the current year's leader was compared with that of the 1935 leader, and the length and volume of the current year's needles were recorded.

In general, all living trees on both plots are making good recovery. Only one tree died during 1937, bringing the total dead to two trees out of 78. Six trees showed no leader growth during 1936, but all had established new leaders by the fall of 1937. The average 1936 leader growth was only 58.7 percent of the 1935 growth, while in 1937 the average leader growth was 97.2 percent of that in 1935. The 1936 foliage was only 86.6 percent of normal, while the 1937 foliage was considered normal.

In examining these plots one of the most noticeable features is the variation in the severity of injury within a comparatively small area. Obviously, all of the trees within a plot must have been subjected to nearly the same temperatures, and thus the answer must lie in the physiological condition of individual trees at the time of the freeze. Table I shows the differences in the injury and recovery

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1/ Plots established May 13, 1936 by H. J. Rust and W. D. Bedard. Examined October 13, 1936 and December 4, 1937 by J. C. Evenden and W. D. Bedard.

on both plots as a result of tree height. In making the examination the 1935 foliage was considered normal, and the 1936 and 1937 needles were compared with this on the basis of density and length. Recovery is expressed therefore in percentages to show how the 1936 and 1937 needles and leaders compare with the 1935 foliage and leaders.

Table I

VARIATION IN INJURY AND RECOVERY AS A RESULT OF TREE HEIGHT

Tree height	Trees examined	Defoliation	Bud mortality	Recovery: Foliage 1936	Recovery: Foliage 1937	Recovery: Leader length 1936	Recovery: Leader length 1937
Feet	Number	Percent	Percent	% normal	% normal	Percent of 1935 leader	Percent of 1935 leader
6-15	48	21	8.7	89.1	100	62.5	107.4
16-25	17	44.1	2.3	86.6	100	66.3	83.1
26+	12	56.6	35.7	79.1	100	36.8	75.7

In general, except for slight irregularities in bud mortality and 1936 leader growth, the taller trees suffered the greatest injury and showed the least recovery. In explanation of this the 1937 report stated, "..... all trees were more severely defoliated at the top than at the base. There are at least three possible reasons why greater defoliation occurred at the top of the tree. Physiologically, the lower branches should be the first to prepare themselves in response to lower temperatures both from the standpoint of shorter conducting tissue, as well as lower photosynthetic rate. Climatically, the lower branches should be in a somewhat warmer environment owing to the protection afforded by surrounding trees. In addition, it is possible that radiation from the earth may have provided some protection."

Table II shows the correlation when injury and recovery are compared with tree dominance. This table includes all trees on both plots, except dead trees.

Table II

VARIATION IN INJURY AND RECOVERY
AS A RESULT OF DOMINANCE

Dominance	Trees examined	Defoliation	Bud mortality	Recovery			
				Foliage		Leader length	
				1936	1937	1936	1937
	Number	Percent	Percent	Percent normal		Percent of 1935 leader	
Dominant	31	34.1	13.8	87.5	100	59.5	91.2
Codominant	27	17.7	4.0	90.8	100	61.1	106.4
Suppressed	19	26.8	17.8	80.0	100	56.0	102.1

It appears that this table is somewhat of a contradiction to table I because the dominant trees do not appear to have suffered the severe damage which was noticeable in the tallest trees in table I. This apparent discrepancy results, however, from the differences in the two plots from which these data were taken. Plot No. 1 contained taller trees than Plot No. 2. Defoliation was also more severe on plot No. 1. Hence, on the basis of height, the taller trees would appear to have suffered a decidedly greater damage. On the basis of dominance, however, both plots are given equal weights because the tallest trees in plot No. 2 are grouped with the tallest trees in plot No. 1, etc.

Table II does show, however, that recovery is more or less proportionate to the severity of the injury. This is more clearly demonstrated in table III in which recovery is compared directly with the

degree of injury.

Table III

COMPARISON OF RECOVERY WITH DEGREE OF INJURY

Percent bud mortality	Percent defoliation									
	0-50					51-100				
	Number trees	Foliage		Leader		Number trees	Foliage		Leader	
		1936	1937	1936	1937		1936	1937	1936	1937
		% normal		% 1935 leader			% normal		% 1935 leader	
0-50	64	93.3	100	67.0	101.2	5	93.3	100	34.0	92.0
51-100	0	-	-	-	-	8	30.0	100	11.1	73.7

Although most of the trees on the two plots fall in the group of least injury, it is apparent that the greater injury results in slower recovery. Both of the dead trees, although excluded from this table, fall in the group showing the severest injury.

An attempt was made during the 1937 examination to secure increment cores from some of the larger trees in order to compare ring growth before and after the cold period. The trees were frozen at this time, however, so that only five cores were secured. The core data are shown in table IV, although a more complete set of cores will be taken at the time of the next examination.

Table IV

EFFECT OF DEFOLIATION ON GROWTH

Tree	Defoliation	Bud mortality	Width of ring 1935	Width of ring 1936	Width of ring 1937	1936	1937	Foliage 1936	Foliage 1937	Leader 1936	Leader 1937
	Percent	Percent	mm	mm	mm	% 1935 ring		% normal		% 1935 leader	
764	21-30	0	5.76	3.47	6.51	60.2	113.0	100	100	50	75
772	51-60	51-60	4.48	1.35	1.85	30.1	41.2	100	100	20	20
761	71-80	31-40	3.53	.86	1.76	24.3	49.8	100	100	50	50
751	71-80	50	6.43	.81	2.20	12.5	34.2	75	100	0	100
758	61-70	81-90	4.94	.90	.70	18.2	14.1	Very sparse	100	0	100

As only five cores were used in table IV, no conclusions can be drawn. It is interesting to note, however, that recovery in radial growth appears to be in direct ratio to the severity of the injury. Tree 758 which suffered 61-70 percent defoliation and almost complete bud mortality shows no recovery in radial growth during 1937, in all probability as a result of the energy expended in producing a normal crop of foliage and a normal leader growth. Where foliage was normal and leader growth fair in 1936, the greatest recovery is shown in radial growth; but where foliage was below normal and the terminal bud killed, greatest recovery is shown in the production of foliage and leader.

Mature Western White Pine

This group includes 41 large trees, 20 of which are in the Twelvemile Creek drainage of the Cabinet National Forest,[1] 7 in the

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[1] Plot established by T. T. Terrell, H. J. Rust, and W. D. Bedard. Examined October 13, 1936 by J. C. Evenden and W. D. Bedard.

Steamboat Creek drainage, and 14 on the divide between Cabin and Rampike Creeks on the Coeur d'Alene National Forest.[1/] Because of the large size of these trees the injury was determined by an estimate of the amount of defoliation, while recovery was ascertained by the amount of growth during 1936 and 1937 as shown by increment cores.

In general, the mature white pine trees are showing but little recovery from the defoliation, and most of the recovery occurs in trees with but slight defoliation. One tree in Steamboat Creek with 50 percent defoliation and one tree on the Rampike-Cabin divide with 90 percent defoliation were attacked and killed by the mountain pine beetle during 1937. In two trees the upper half of the crown died during 1937, while one other tree showed decidedly etiolated foliage when examined in 1937. This latter tree grew only .01 mm during the current year as compared with .40 in 1935 and .07 in 1936. The average growth for all defoliated white pine trees was .38 in 1937 as compared with .42 in 1936 and .91 in 1935.

Table V shows the average growth during the past three years according to the degree of defoliation. The cores from the trees in the Twelvemile Creek drainage have been excluded from this year's report because they were so slightly defoliated that they showed practically no retardation in growth.

1/ Trees marked by T. T. Terrell. Examined Nov. 4, 1936 and Nov. 17, 1937 by T. T. Terrell and W. D. Bedard.

Table V

COMPARISON OF GROWTH BEFORE AND AFTER DEFOLIATION
ACCORDING TO DEGREE OF INJURY

Defoliation	Average width of ring 1935	1936	1937	Percent 1936 ring is of 1935 ring	Percent 1937 ring is of 1935 ring
Percent	mm	mm	mm		
0-20	1.29	1.14	1.52	88.3	117.7
21-40	.91	.50	.37	54.9	41.0
41-60	.91	.54	.32	59.3	35.1
61-80	1.69	.58	.42	34.3	24.8
81-100	.40	.11	.16	27.5	40.0

It is apparent in table V that recovery is more or less directly dependent on the amount of defoliation. Trees with less than 20 percent defoliation have recovered completely, while trees with more than 20 percent defoliation, except for the most severely defoliated group, made poorer growth during 1937 than in the year immediately following the cold period. The cause of the rapid recovery shown in the most severely defoliated group is difficult to place, but in all probability rests with the rate of growth. As will be shown later, the slower-growing trees are making the most recovery, and as the 81-100 group in table V comprises four of the most slowly growing trees, this probably causes the irregularity in the correlation.

Table VI shows the injury and recovery according to the rate of growth.

Table VI

INJURY AND RECOVERY BASED ON
RATE OF GROWTH

Av. width last 10 rings	Average defoliation	Av. width ring 1935	1936	1937	Percent 1936 ring is of 1935 ring	Percent 1937 ring is of 1935 ring
mm	Percent	mm	mm	mm		
2.01+	18	2.77	1.92	.43	69.3	15.5
1.51-2.0	14	1.66	1.26	.82	75.9	49.3
1.01-1.5	22	1.26	.95	.37	75.3	29.3
.51-1.0	28	.77	.61	.29	79.2	37.6
0-.50	51	.37	.24	.24	64.8	64.8

Although previous tables have shown that recovery is more or less dependent on the severity of the injury, there have been irregularities which probably have been due to growth rate of the tree. As shown in table VI there is a marked correlation between growth rate and recovery, the slower-growing trees making the greatest recovery in spite of the fact that they suffered the severest injury. The irregularity shown in the 1.51-2.0 group probably results from less severe defoliation.

In explanation of this paradoxical situation, the previous report stated, "......it is possible that the more rapidly growing trees with their more abundant conducting tissues are able, under sudden climatic changes, to make a more rapid translocation or change of materials than the trees of slower growth. Thus, they are able to avoid the disastrous effects of the freeze. When growth is resumed, however, following the low temperatures, those trees growing under optimum conditions would naturally show a greater reaction to foliage

loss than would the more slowly growing trees. This has been shown to be true in cases of drought and insect defoliation. Obviously there is a point at which the effects of the loss of foliage must be shown by even the slowest growing trees....."

Mature Ponderosa Pine

A total of 40 mature ponderosa pine trees were tagged[1/] in the vicinity of Coeur d'Alene, Idaho for this study. In general, these trees were defoliated approximately to the same extent as the western white pine trees, but are showing a decidedly better recovery. Table VII gives a comparison of recovery in white pine and in ponderosa pine.

Table VII

AVERAGE GROWTH RINGS IN WHITE PINE
AND PONDEROSA PINE

Tree	Average defoliation	Average growth all trees					
		1937	1936	1935	1934	1933	1932
White pine	59	.38	.42	.91	1.19	1.07	1.10
Ponderosa pine	56	1.48	1.02	1.95	2.55	2.09	2.06

In white pine the average 1936 ring is 46.1 percent as wide as the 1935 ring, and only 41.7 percent as wide in 1937. In ponderosa pine the 1936 ring is 52.3 percent and the 1937 ring 75.8 percent of

1/ Marked by H. J. Rust and examined by him November 4, 1936 and November 4, 1937.

the 1935 ring. It is also noticeable in this table that the 1935 ring is somewhat smaller than in previous years. This fact is probably a result of the fall freeze which stopped further growth during that year.

Table VIII compares the growth in ponderosa pine before and after injury, according to the amount of defoliation.

Table VIII

COMPARISON OF GROWTH BEFORE AND AFTER DEFOLIATION ACCORDING TO DEGREE OF INJURY

Defoliation	Av. Width of ring			Trees with no ring		Percent ring is of 1935 ring	
	1935	1936	1937	1936	1937	1936	1937
Percent	mm	mm	mm	Number	Number		
0-20	3.03	1.66	2.74	-	-	54.7	90.4
21-40	2.65	1.91	1.47	-	-	72.0	55.4
41-60	2.11	1.22	1.47	-	-	57.8	69.6
61-80	1.29	.27	1.31	9	0	20.9	101.5

Here again it is apparent that recovery is not entirely dependent upon the severity of the injury. Although the 0-20 defoliation group made a good recovery, it is exceeded by that in the group of severest defoliation.

Table IX shows the average injury and recovery according to the rate of tree growth.

Table IX

INJURY AND RECOVERY BASED ON RATE OF GROWTH

Average width last 10 rings	Average defoliation	Av. width of ring			Trees with no ring		Percent ring is of 1935 ring	
		1935	1936	1937	1936	1937	1936	1937
mm	Percent	mm	mm	mm	Number		Percent	
4.01+	42	5.80	2.88	2.99	0	0	49.6	51.5
3.01-4.0	47	3.67	1.77	2.53	0	0	48.2	68.9
2.01-3.0	48	2.48	1.36	1.37	0	0	54.8	55.2
1.01-2.0	58	1.47	.85	1.24	3	0	57.8	84.3
0-1.0	64	.58	.28	.72	6	0	48.2	124.1

In table IX it is again apparent that rate of growth is the important factor in determining the degree of injury and recovery. There is a definite increase in amount of defoliation from the most rapidly growing trees to the slowest growing ones, and an increase in the amount of recovery in the same direction, excepting the 3.01-4.0 group.

SUMMARY

1. Sudden freezing temperatures during October 1935 resulted in the death of pine foliage.

2. Following this defoliation trees were marked to include white pine reproduction, mature white pine, and mature ponderosa pine to determine if the defoliation would make the trees more susceptible to insect attack.

3. During the two years subsequent to the freeze two mature white pine trees have been attacked and killed by the mountain pine beetle and two trees on the white pine reproduction plots have died as a direct result of almost complete defoliation. The two small trees were not attacked by insects.

4. In white pine reproduction the tallest trees suffered the greatest amount of injury. Recovery appears to be in direct proportion to the amount of injury.

5. In mature ponderosa and white pine the greatest injury occurred in those trees making the slowest growth. Recovery, on the other hand, was greatest in the slower-growing trees, except when defoliation was so severe as to prevent any great recovery.

Respectfully submitted,

W. D. Bedard
Associate Entomologist